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(54) **Working glass objects and the like by laser radiation**

(57) Method and apparatus for working the surface of glass objects and the like by infrared laser radiation where an electric signal from an optical pick-up device scanning a pattern controls the laser discharge so that the impinging laser radiation causes a change in the optical permeability of the glass and/or evaporation of glass material solely along a line or over an area, corresponding to the pattern.

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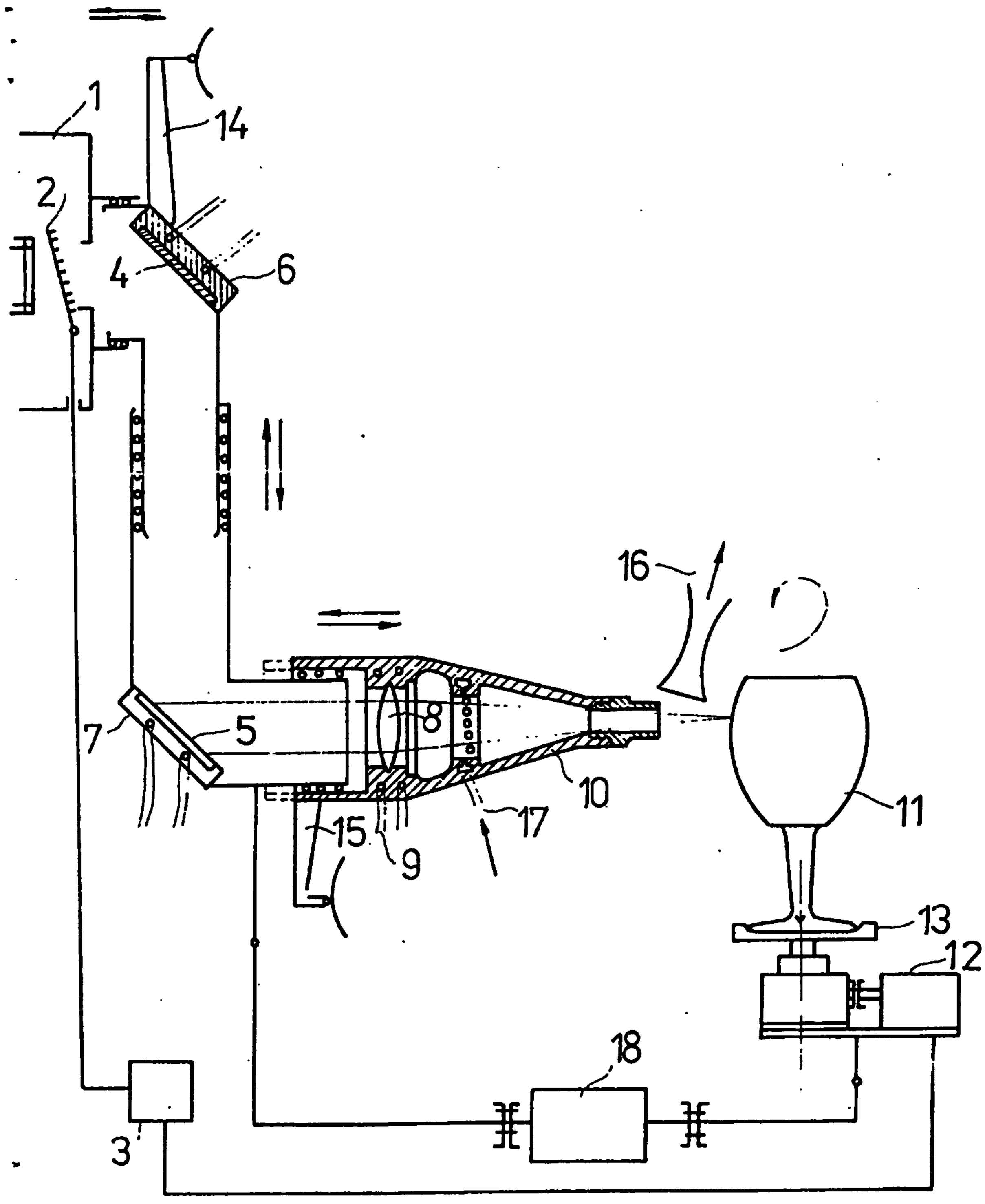

FIG. 1

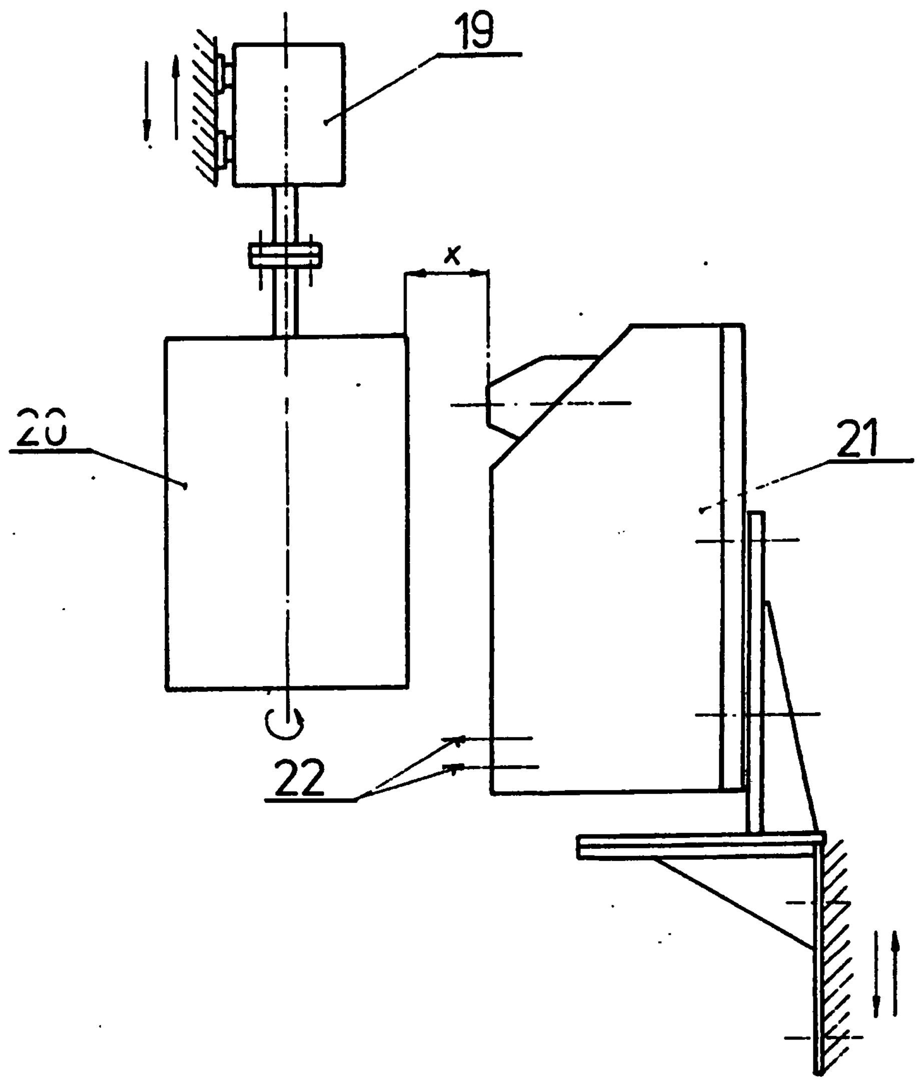

FIG. 2

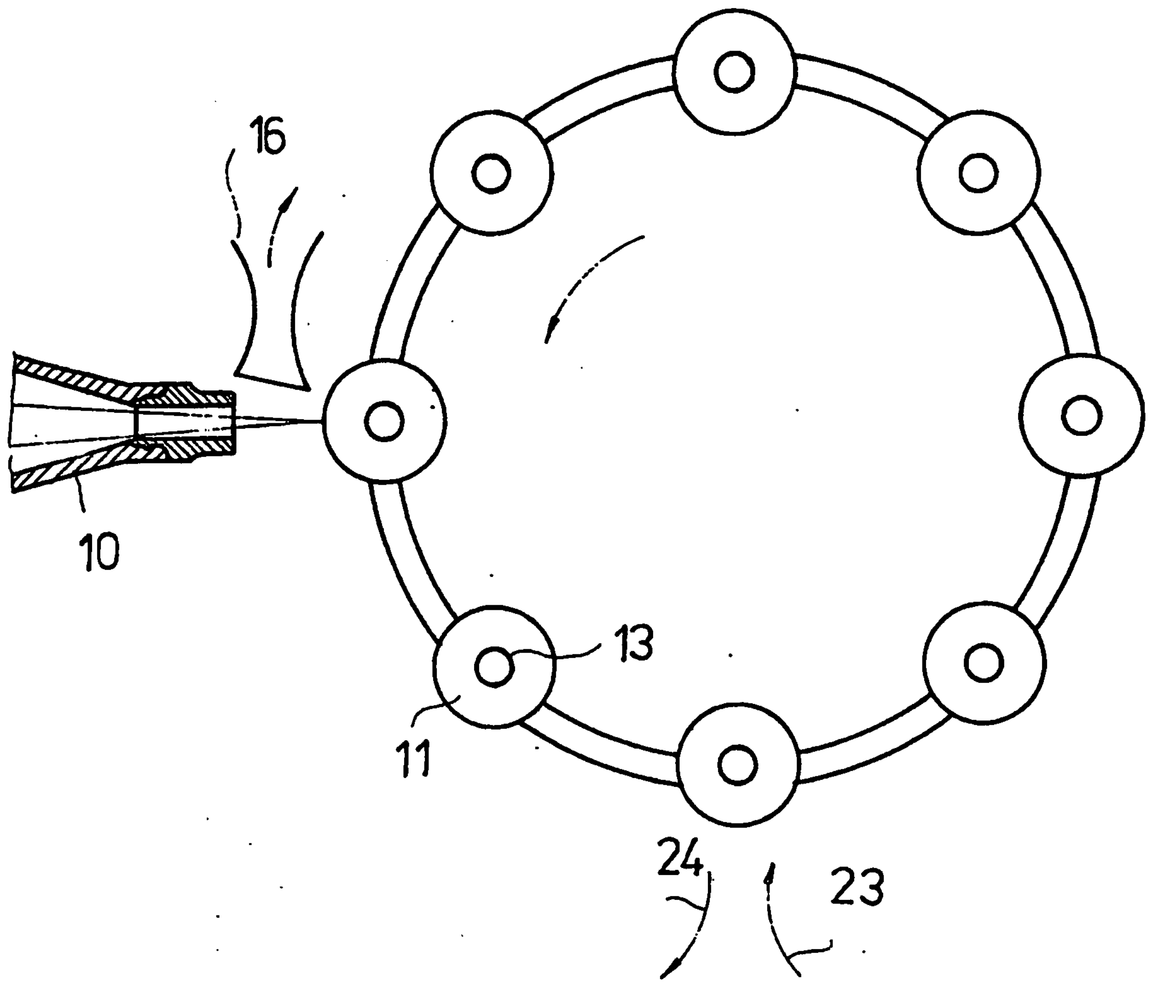

FIG. 3

SPECIFICATION

Method and apparatus for working the surface of glass objects and the like by laser radiation

The invention relates to a method for working of the surface of glass objects and the like, such as glass ceramics, ceramics, glazed materials, artificial materials or wood, by laser radiation using an electrical signal from an optical pick-up device scanning a pattern, and to an arrangement for the execution of this method, for utilization in the decorative arts, particularly in the glass industry.

The surface of glass objects can be worked by laser radiation where there is at least 50% absorption at the wave length used, and since currently used utility and technical glass is nearly impermeable at wave lengths in the infrared spectrum with very high absorption coefficients, a laser for working glass surfaces with an output in the infrared spectrum is particularly convenient.

The working of glass objects by laser radiation is in a physical sense an interaction of laser radiation with glass, the result of which can be the evaporation of a certain mass of glass from the required line or area of the worked object, and is in fact principally the removal of glass mass from the glass object.

According to this principle and according to the visual character of the surface of the worked object it is possible to compare the method of working surfaces of glass objects by laser radiation to pantographing with subsequent etching with hydrofluoric acid, the technology of mat grinding, the technology of chemical matting and to a certain extent also, to the technology of working by diamonds.

It is possible to obtain with the mentioned classical methods worked lines or areas on glass objects comprising closed curves or repeatedly closed areas. The commonly used classical technology is that of pantographing with subsequent etching with hydrofluoric acid. This classical method is, however, rather demanding and costly regarding hygiene and safety regulations, and requires a number of operations which are performed manually and are rather elaborate. Thus, working objects using this method is time consuming, and any change of pattern so demanding on time that decorating a small number of objects is not economical.

Another known method based on the removal of glass mass from a glass object is the method of working by laser radiation as described in the patent specification No. 112.941 of the German Democratic Republic. According to this method the interaction of the laser radiation with the glass object is governed by a time switch adapted to be controlled, or by means of metal masks. However, a drawback of this method and of the arrangement is that it is not possible to obtain a line or worked area of glass in the shape of a closed curve or of a repeatedly closed area. Another drawback is the demanding preparation of metal masks and their limited life. The preparation of a programme for the time switch is, in current practice, equally rather demanding.

It would therefore be desirable to provide a method and an arrangement for working surfaces of glass objects by infrared radiation which would be less demanding on time and apparatus than known methods, and which would enable closed curves and repeatedly closed areas to be worked on glass objects.

Thus, the present invention provides a method for working the surface of glass objects and the like by infrared laser radiation causing a change in the optical permeability of the glass and/or an evaporation of the mass of the glass material so that this change/evaporation corresponds to the time course of the impinging infrared laser radiation wherein the infrared laser radiation impinges on an axially-symmetrical glass object so that the object absorbs the radiation in a surface layer of thickness 10^{-7} to 5 mm and the time course of the impinging laser radiation is electrically controlled "on-line" according to corresponding lines and areas of a pattern, while conditions of synchronization of rotatory and translatory movements around and in the direction of the axes of symmetry of the pattern and the worked axially-symmetrical glass object are maintained.

The maximum density of infrared laser radiation is dynamically localized in the region of the surface of the worked axially-symmetrical glass object.

In apparatus for carrying out the method of the invention a laser is electrically connected to an optical pick-up device for scanning the surface of the pattern and electrical signals from the device are used to control the discharge of the laser.

In particular the apparatus may comprise a laser, a shutter, an external logic, a lens, mirrors, a gas nozzle, a clamping mechanism and drives for rotatory and translatory movements wherein the laser is electrically connected "on-line" with the optical pick-up device through an amplifier, a frequency generator and a comparator for on/off control thereof.

The original pattern is situated on a body having the shape of a cylinder or the shape of the worked axially-symmetrical glass object, and preferably is also the same size as the glass object. When this body has the shape of a cylinder, the pattern first has to be descriptively adjusted so as to obtain on the axially-symmetrical glass object the required decorative effect of lines and areas corresponding to the original pattern of lines and areas. The drives for rotational and translatory motion can be interconnected with the copying device for dynamically locating the focus of the lens on the surface of the axially-symmetrical glass object. A suction device situated close to the focus of the lens removes products of interaction of laser radiation with the glass.

The main advantage of the method for working the surface of glass objects by laser radiation according to this invention and of the arrangement for execution of this method is that the variety of

decorated objects is not limited, and a change of the required pattern is very quick, so that manufacturing a small number of objects with a particular pattern is economical. Another advantage is the very high speed of working the surface of glass objects, enabling the introduction of the method and apparatus into a manufacturing line for mass manufacture of goblets and cups. By application of a suction device, a carousel transporter of glass objects and an external logic, the required hygiene and safety is achieved, particularly the protection of attendants from laser radiation and from inhaling possible obnoxious gases or particles of products of interaction of radiation and glass.

An exemplary embodiment for execution of the method for working the surface of glass objects by infrared laser radiation according to this invention is shown in the attached drawings, where

Fig. 1 is an elevation of the decorating arrangement,

Fig. 2 an elevation of the optical pick-up system, and

Fig. 3 a diagrammatical top view of a carousel conveyor for glass objects.

The arrangement for execution of the method for working the surface of glass objects by infrared laser radiation shown in Fig. 1 comprises a laser 1, a shutter 2, an external logic 3 for control of the output of the laser 1, an optical system comprising mirrors 4 and 5 with cooling 6 and 7 and a lens 8 with cooling 9 situated in a gas nozzle 10 with gas supply 17, a clamping mechanism 13 for centric clamping of the glass object 11, a first copying device 14 or a second copying device 15, a suction device 16, a first drive 12 for the rotational movement of the object 11 and a second drive 18 for a translatory movement. A further part of the arrangement shown in Fig. 2 is an optical pick-up device 21, a body 20, the output 22 of the pick-up device 21 and a third drive for a rotational movement of the body 20.

The simplest exemplary embodiment of the method and arrangement is if the worked axially-symmetrical glass object 11 has the shape of a cylinder and the body 20 for accommodation of the pattern of cylindrical shape are situated so that their axes are in a single line, whereby they are rotating around their axes of symmetry, so that either the circumference or angular speed of their surfaces is constant, whereby they perform synchronously a linear movement in the direction of their axes of symmetry. The lens 8 focusing the CO_2 beam of the laser 1 is situated so that the optical axis of the lens 8 is perpendicular (this is however not a limiting condition) to the axis of symmetry of the worked axially-symmetrical glass object 11 and the focus of the lens 8 is dynamically localized on the surface of the worked axially-symmetrical object 11. The optical pick-up system for the pattern is situated as is common to classical telephoto transmitters. The electrical signal from the optical pick-up device 21 is arranged so that it causes at an "on-line" connection with the radiation control of the laser 1 an "on-line" on/off control of the radiation of the laser 1 according to the pattern. Under these conditions the laser 1 operates continuously and decorates the glass object according to the original pattern. The quality of the copied or reproduced pattern and its visual character can also be influenced by a pulsating operation of the laser.

The decorating arrangement for the method of working the surface of glass objects is shown in Fig. 1 where a rotational movement of the axially-symmetrical glass object 11 around its axis of symmetry and a translatory movement of the focus of the lens 8 along a trajectory secure a relative movement between the focus of the lens 8 and the surface of the axially-symmetrical glass object 11. The arrangement is characterised in that it uses a clamping mechanism 13 securing a centric clamping of the axially-symmetric glass object 11 and requires as fundamental movement the rotation of the axially-symmetric glass object 11 around its own axis of symmetry. The output of the beam from the aperture of the laser 1 is controlled by a shutter 2. The shutter is opened when the carousel brings the axially-symmetric glass object 11 to the position for working, i.e. when the surface of the worked axially-symmetrical glass object 11 is in the focus of the lens 8. The opening and closing of the shutter 2 is controlled by the external logic 3 according to cycles of the carousel.

The optical system through which the radiation of the laser 1 passes comprises two mirrors 4 and 5 and a lens 8. The reflecting surfaces of the mirrors 4 and 5 must be of a material with high reflection coefficient on the wave length used by the laser 1. According to the material used for the mirrors 4 and 5, the quality of the mirrors 4 and 5 and the output of the radiation of the laser 1 it is possible to determine whether a cooling 6 and 7 of the mirrors 4 and 5 by water is required. The radiation of the laser 1 reflected from the mirror 5 impinges on the lens 8. If necessary the lens 8 is provided with a coaxial cooling 9 by water. The lens 8 focuses the radiation of the laser 1 on the surface of the worked axially-symmetrical glass object 11. The lens 8 is situated in the gas nozzle 10 with a gas supply 17. The first drive 12 secures a rotational movement of the worked axially-symmetrical glass object 11 which is clamped by the clamping mechanism 13. The surface of the axially-symmetrical glass object 11 is dynamically localized in the focus of the lens 8.

The mirror 5 with the cooling 7, the lens 8 and the gas nozzle 10 with cooling 9 perform a constrained translatory motion determined by the speed vector *v*; the direction of the speed vector *v* is parallel with the rotation axis of the axially-symmetrical glass object 11, the magnitude of the speed vector *v* is in the course of working independent of time, the orientation of the speed vector *v* is determined by the arrangement and limiting conditions of working. The translatory movement of the system; mirror 5 with cooling and lens 8 with cooling 9 relative to the mirror 4

with cooling 6 secures the second drive 18. The first copying device 15, secures the dynamic localization of the lens 8 on the surface of the axially-symmetrical glass object 11 in the course of working. The copying movement can be transformed either to a movement of the system of mirrors 4 and 5 with cooling 6 and 7 of the lens 8 with cooling 9 with respect to a fixed point on the laser 1 or to a movement of the lens 8 with cooling 9 with respect to the mirror 5 with cooling 7 in direction of the axis of the resonator of the laser 1. The height of working of the surface of the axially-symmetrical glass object 11 in the direction of the axis of symmetry is determined by the overall displacement of the focus of the lens 8 in the direction of the axis of symmetry of the axially-symmetrical glass object 11. Generated components from the interaction of the radiation of the laser 1 with the glass are removed from the working zone by the suction device 16.

Fig. 2 shows an elevation of the optical pick-up system. The main condition of functioning of the optical pick-up system is an unconditional synchronization of revolutions of the worked axially-symmetrical glass object 11 and of the body 20. Another condition is the synchronization of the translatory movements; the relative movement of the focus of the lens 8 — worked axially-symmetrical glass object 11 and the relative movement of the optical pick-up device 21 — body 20. The third drive 19 secures the revolutions of the body 20. It is common for the body 20 to have a hollow cylindrical shape. The original pattern, usually a photographic picture, which is scanned by the optical pick-up device 21 is situated on the body at a distance X. If the worked axially-symmetrical glass object 11 is not of cylindrical shape and the body 20 has a cylindrical shape, it is necessary to provide in advance a descriptive representation of the original pattern in order to obtain a required working line or area for working the axially-symmetrical glass object 11.

The electrical signal from the output 22 of the optical pick-up device 21 is, after adjustment, introduced into the control block of the laser 1, where the "on-line" on/off mechanism controls the radiation in the resonator of the laser 1 according to information from the original pattern. A signal which subsequently secures through the control block of the laser 1 a pulse or gate condition of the laser 1 can also be superposed on the electric signal.

The synchronization of the relative translatory movements of the optical pick-up device 21 with the body 20 and of the focus of the lens 8 with the worked axially-symmetrical glass object 11 can be obtained by mechanical coupling (forced motion) or by electrical synchronization of the drives. It is advantageous to use step by step drives for the control of all movements of the described arrangement. The application of DC or asynchronous electric motors is however also possible, as is the use of hydraulic or pneumatic means (pressure means).

Fig. 3 shows diagrammatically a top view of a carousel method of transport of axially-symmetrical glass objects 11 from their position of manual insertion in the clamping mechanism 13 in direction 23, to their removal in direction 24, which positions are removed from the position of interaction of laser radiation with the glass objects 11. The products of interaction of radiation of the laser 1 with the axially-symmetrical glass object 11 are removed by the suction device 16. The minimum number of clamping mechanisms 13 on the carousel is 2, the maximum number 24. The transport of glass objects at a number of clamping mechanisms larger than 2 is unidirectional, at a carousel with two positions the transport of objects can also be reciprocal, i.e $\pm 180°$.

The realization of working the surface of glass objects by infrared laser radiation can also be accomplished by securing a relative movement: focus of lens 8 — surface of the axially-symmetrical glass object 11, so that the focus of the lens 8 does not move in the direction of the axis of symmetry of the worked axially-symmetrical glass object 11 and the required translatory movement in the direction of the axis of symmetry is performed by the axially-symmetrical glass object 11. In that case the required mirrors 4 and 5 with cooling 6 and 7 and the lens 8 with the cooling 9 are not situated in the direction of the optical axis of the resonator of the laser 1. This method is however not suitable when using a carousel with more than two positions, as the movement of the focus of the lens 8 is energetically and spatially more advantageous. The optical pick-up system can be, for instance, realized according to the simplest principle of the optical pick-up of classical telephoto transmitters. A suitable laser for working the surface of glass is, for instance, a CO_2 laser of an output 10 to 1000 W.

This method of working the surface of glass objects by infrared radiation and the respective arrangement for its execution are also suitable for working the surface of like materials such as ceramics, glass-ceramics, glazed materials, artificial material, wood. When these materials are worked, the values of parameters of movement and synchronization have to be adjusted. This method of working the surface of axially-symmetrical glass objects by laser radiation is also suitable for working utility glass, the surface of which is coloured in a thin surface layer by the lazuration technique, so that it is optically visually partly permeable.

CLAIMS

1. Method for working the surface of glass objects and the like by infrared laser radiation causing a change in the optical permeability of the glass and/or an evaporation of the mass of the glass material so that this change/evaporation corresponds to the time course of the impinging infrared laser radiation wherein the infrared laser radiation impinges on an axially-symmetrical glass object so that the object absorbs the radiation in a

surface layer of thickness 10^{-7} to 5 mm and the time course of the impinging laser radiation is electrically controlled "on-line" according to corresponding lines and areas of a pattern, while conditions of synchronization of rotatory and translatory movements around and in the direction of the axes of symmetry of the pattern and the worked axially-symmetrical glass object are maintained.

2. Method for working the surface of glass objects and the like by infrared laser radiation as claimed in Claim 1 wherein the maximum density of laser radiation is dynamically localized in the surface region of the worked axially-symmetrical glass object.

3. Method for working the surface of glass objects and the like by infrared laser radiation as claimed in Claims 1 or 2 wherein the radiation is pulsating.

4. Apparatus for carrying out the method claimed in any one of Claims 1 to 3 wherein a laser is electrically connected to an optical pick-up device for scanning the surface of the pattern and electrical signals from the device are used to control the discharge of the laser.

5. Apparatus as claimed in Claim 4 comprising a laser, a shutter, an external logic, a lens, mirrors, a gas nozzle, a clamping mechanism and drives for rotatory and translatory movements wherein the laser is electrically connected "on-line" with the optical pick-up device through an amplifier, a frequency generator and a comparator for on/off control thereof.

6. Apparatus as claimed in Claim 5 wherein the drives for rotatory and translatory movements are connected to a copying device for locating the focus of the lens on the surface of the axially-symmetrical glass object.

7. Apparatus as claimed in Claim 4 wherein a body for locating the pattern has the shape of the worked axially-symmetrical glass object.

8. Apparatus as claimed in Claim 7 wherein the body for locating the pattern has the shape of a cylinder the diameter of which is about equal to the mean diameter of the worked axially-symmetrical glass object.

9. Apparatus as claimed in Claims 7 or 8 wherein the pattern located on the body is in the form of a photographic picture.

10. Apparatus as claimed in Claim 4 wherein a suction device is situated close to the focus of the lens.

11. Apparatus as claimed in Claims 5 or 7 wherein a first drive is provided for rotary motion of the axially-symmetrical glass object, a third drive is provided for rotary motion of the body locating the pattern, said drives comprising electric motors, while a second drive provided for the translatory movement is derived from pressure means.

12. Apparatus as claimed in Claim 5 wherein the position of the clamping mechanism for insertion and for removal of glass objects is removed from the position of the clamping mechanism when interaction of the laser radiation with the glass object occurs.

13. Method for working the surface of glass objects and the like by infrared laser radiation substantially as hereinbefore described with reference to the accompanying drawings.

14. Apparatus for working the surface of glass objects and the like by infrared laser radiation substantially as hereinbefore described with reference to the accompanying drawings.

15. A glass object or the like when worked by the method of any one of Claims 1 to 3 or 13 or the apparatus of any one of Claims 4 to 12 or 14.

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